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Tsukada

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(54) **STOP CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE**

(75) Inventor: **Yuta Tsukada**, Susono (JP)

(73) Assignee: **Toyota Jidosha Kabushiki Kaisha**, Toyota-shi, Aichi (JP)

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B60W 10/06	(2006.01)
B60W 10/08	(2006.01)
F02D 17/00	(2006.01)
F02N 11/08	(2006.01)

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USPC 701/22

See application file for complete search history.

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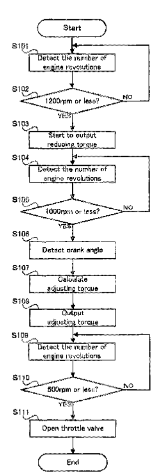
Primary Examiner — Michael Berns

(74) *Attorney, Agent, or Firm* — Finnegan, Henderson, Farabow, Garrett & Dunner, LLP

(57) **ABSTRACT**

A stop control apparatus for an internal combustion engine is provided with: a motor (MG**1**) configured to output torque to a crankshaft (**205**) of the internal combustion engine (**200**); a number-of-revolutions detecting device (**110**) configured to detect the number of revolutions of the internal combustion engine; a crank angle detecting device (**120**) configured to detect a crank angle of the crankshaft of the internal combustion engine; a motor controlling device (**150**) configured to control the motor to output adjusting torque which adjusts the crank angle when the internal combustion engine stops to have a desired value, when the internal combustion engine stops; a throttle valve controlling device (**160**) configured to control an opening degree of a throttle valve (**208**) to be a predetermined opening degree in an intake stroke immediately before the internal combustion engine stops; and an adjusting torque determining device (**140**) configured, to determine the adjusting torque on the basis of the predetermined opening degree and the crank angle when the number of revolutions of the internal combustion engine has a predetermined value. This makes it possible to preferably control the crank angle when the internal combustion engine stops.

4 Claims, 11 Drawing Sheets



(52) **U.S. Cl.**
CPC *B60W2710/0605* (2013.01); *Y02T 10/6239* (2013.01); *Y02T 10/6286* (2013.01); *Y10S 903/93* (2013.01)

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FIG. 1

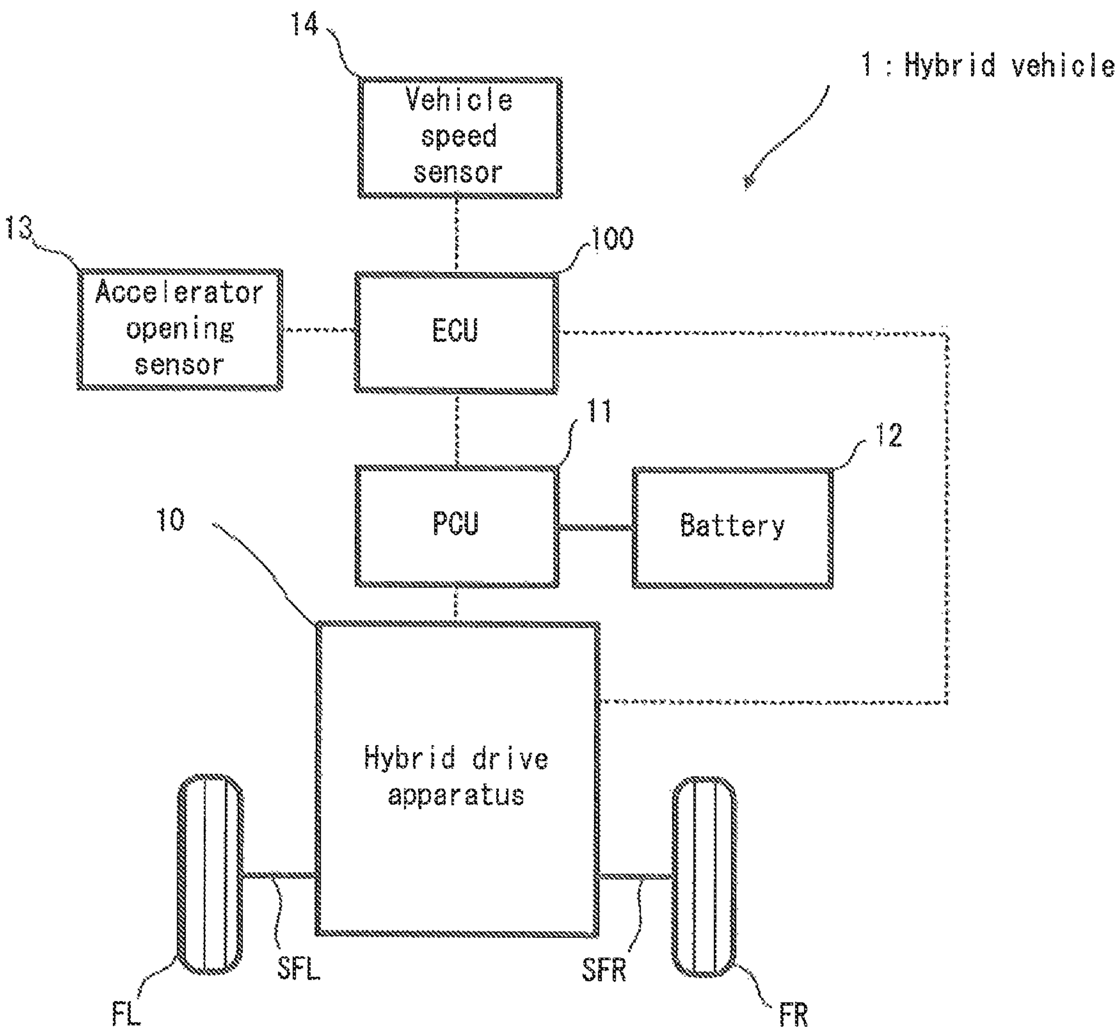

14
Vehicle speed sensor
1 : Hybrid vehicle
13
Accelerator opening sensor
100
ECU
11
12
PCU
Battery
10
Hybrid drive apparatus
SFL
SFR
FL
FR

FIG. 2

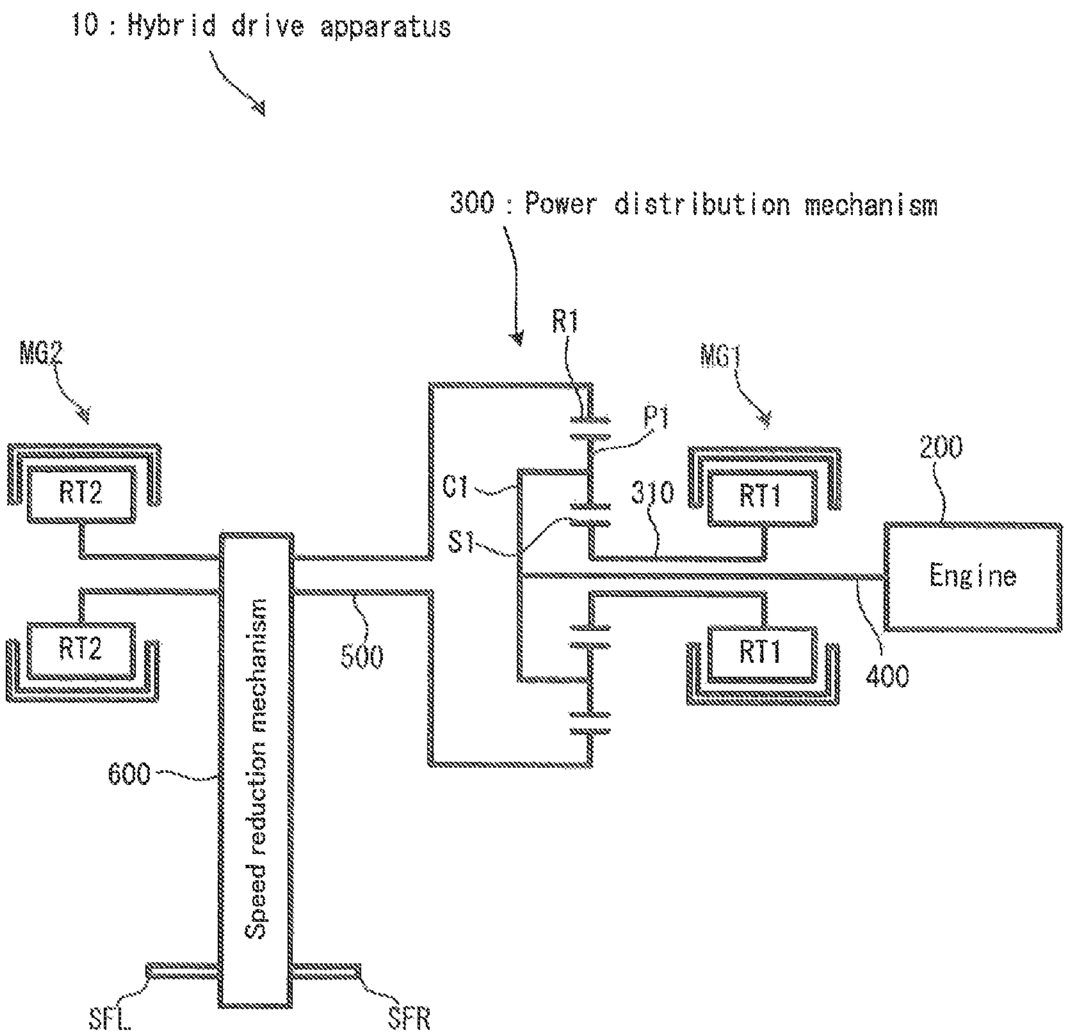
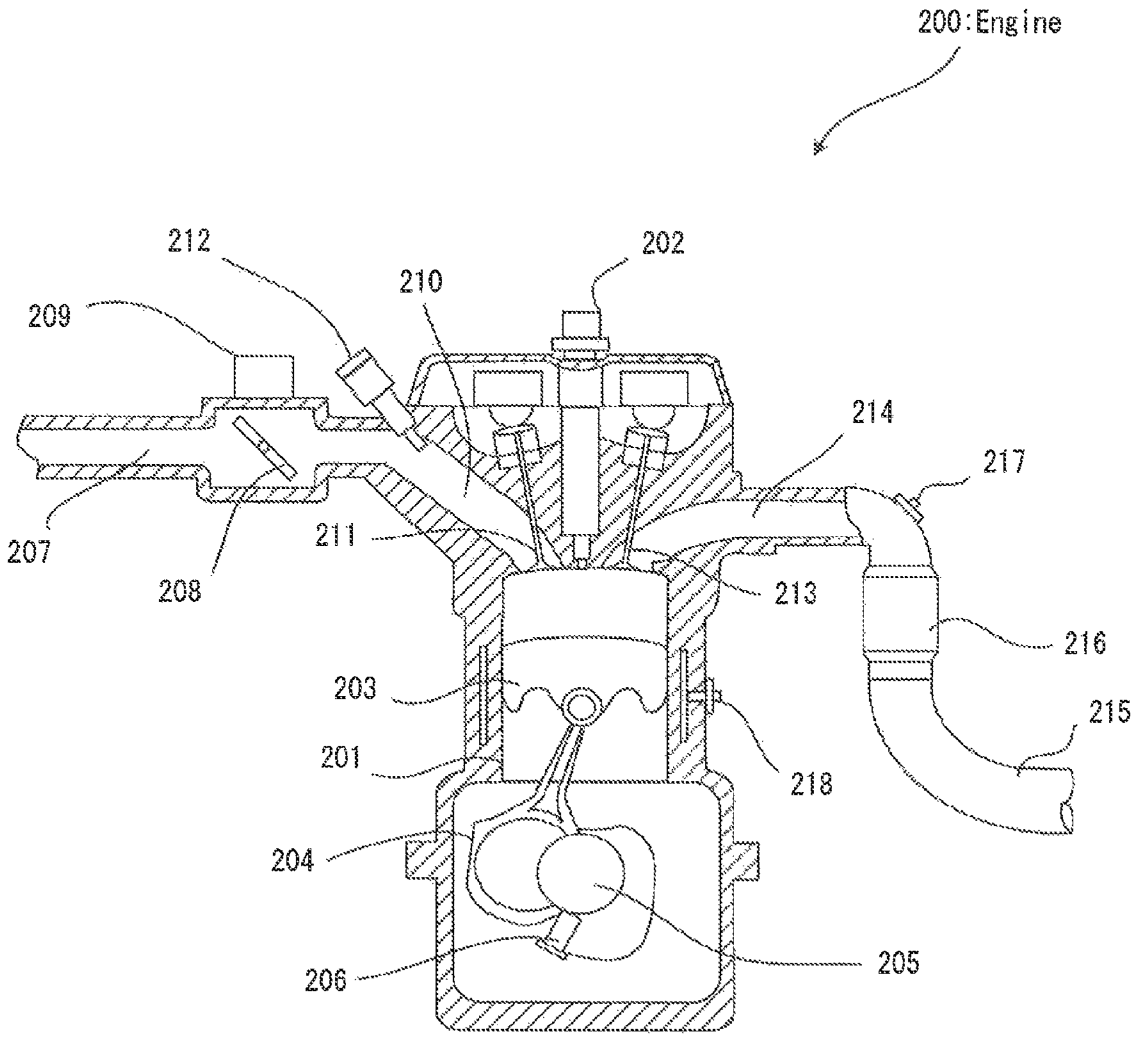

10 : Hybrid drive apparatus
300 : Power distribution mechanism
R1
MG2
MG1
P1
C1
310
S1
RT2
RT1
200
Engine
RT2
RT1
500
400
600
Speed reduction mechanism
SFL
SFR

FIG. 3



200:Engine
212
202
210
209
214
217
207
211
208
213
216
203
215
201
218
204
206
205

FIG. 4

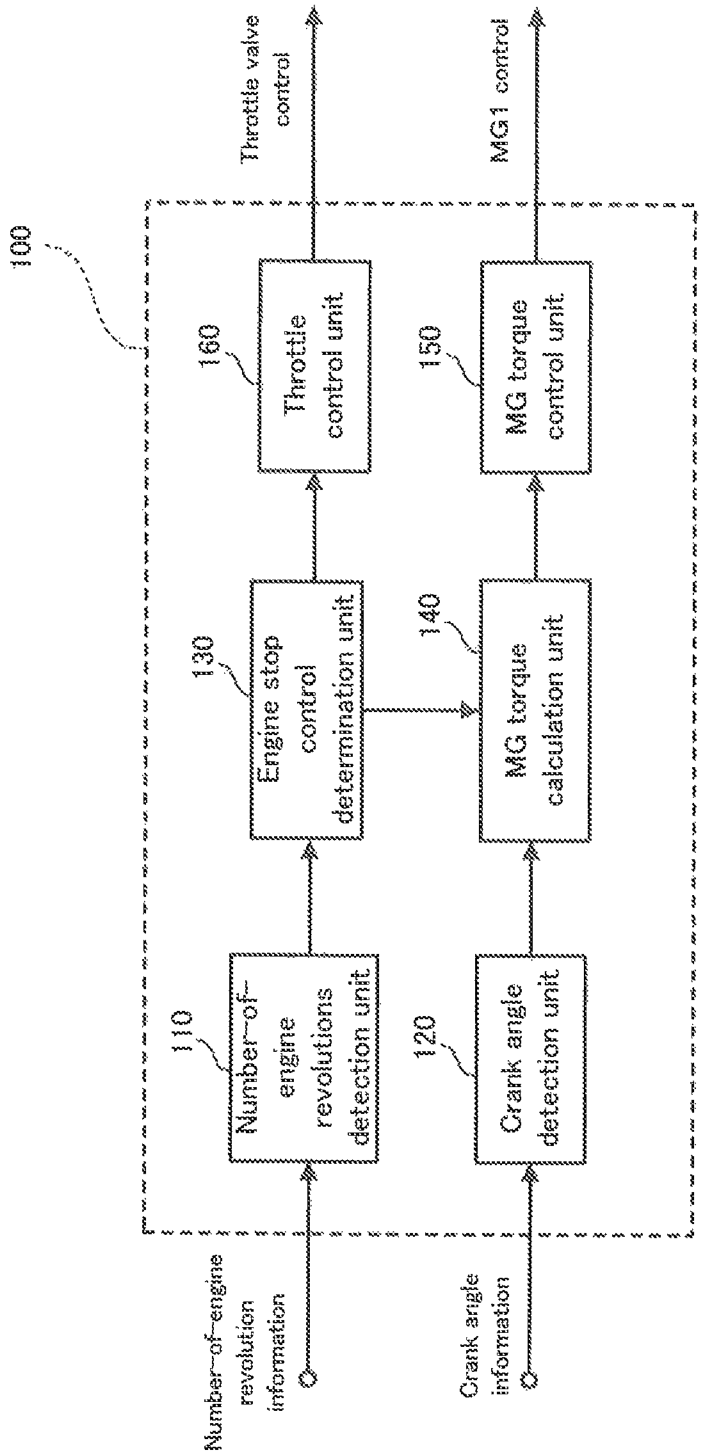

Throttle valve control
MG1 control
100
160
Throttle control unit
150
MG torque control unit
130
Engine stop control determination unit
140
MG torque calculation unit
110
Number-of-engine revolutions detection unit
120
Crank angle detection unit
Number-of-engine revolution information
Crank angle information

FIG. 5

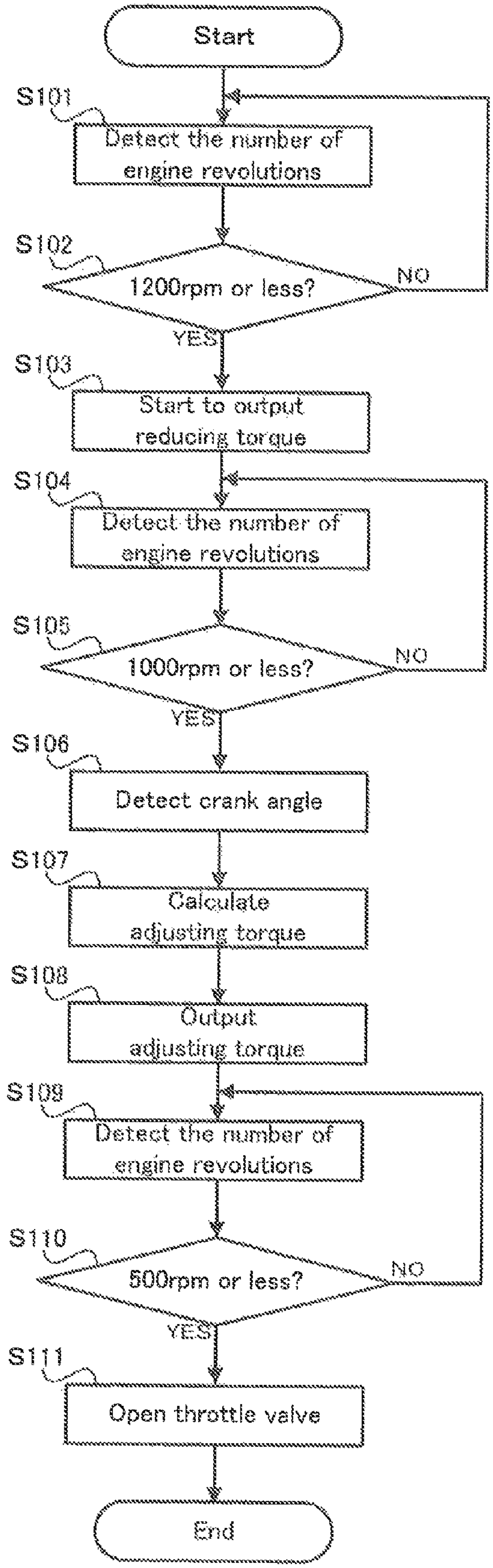

Start
S101
Detect the number of engine revolutions
S102
1200rpm or less?
NO
YES
S103
Start to output reducing torque
S104
Detect the number of engine revolutions
S105
1000rpm or less?
NO
YES
S106
Detect crank angle
S107
Calculate adjusting torque
S108
Output adjusting torque
S109
Detect the number of engine revolutions
S110
500rpm or less?
NO
YES
S111
Open throttle valve
End

FIG. 6

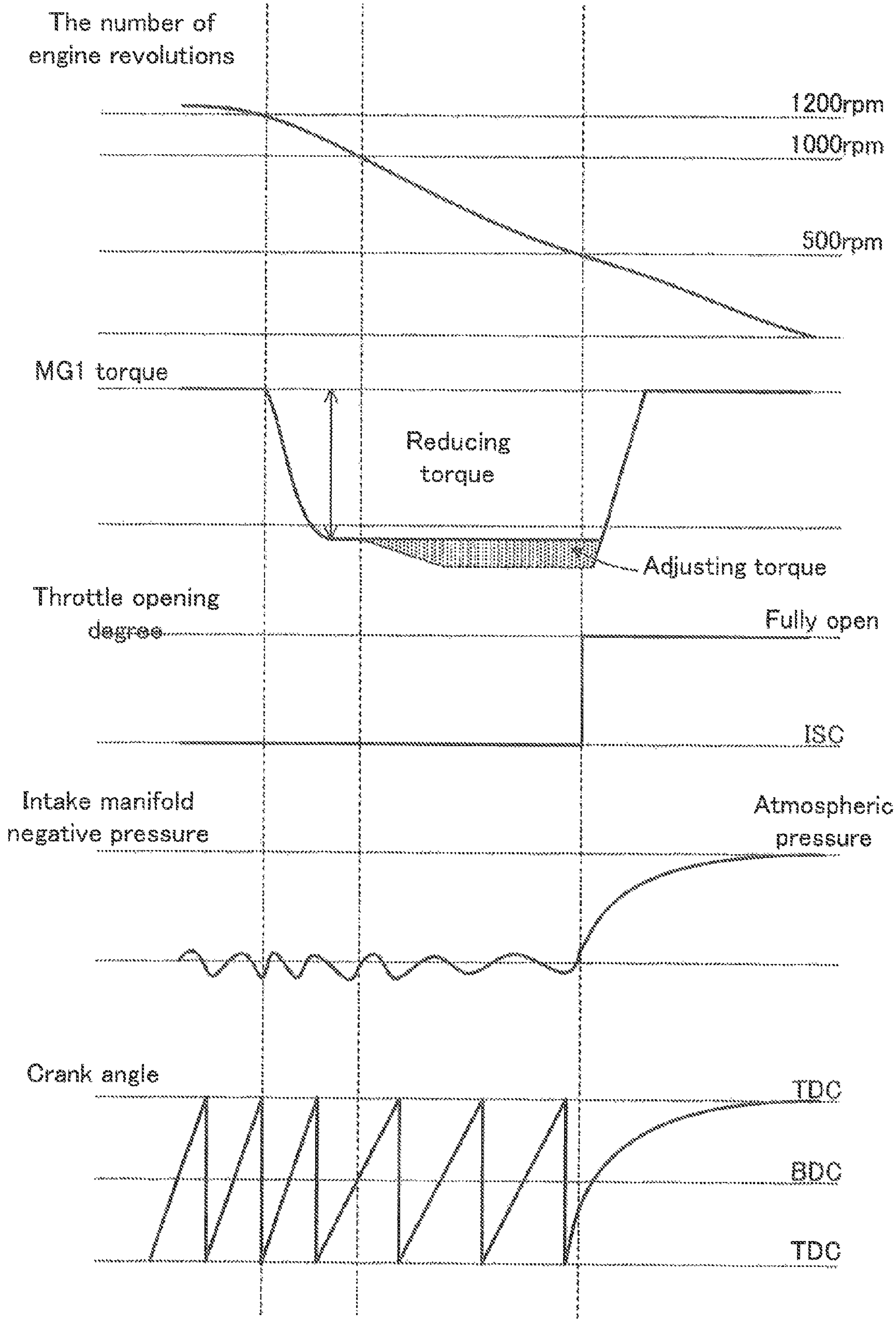

The number of engine revolutions
1200rpm
1000rpm
500rpm
MG1 torque
Reducing torque
Adjusting torque
Throttle opening degree
Fully open
ISC
Intake manifold negative pressure
Atmospheric pressure
Crank angle
TDC
BDC
TDC

FIG. 7

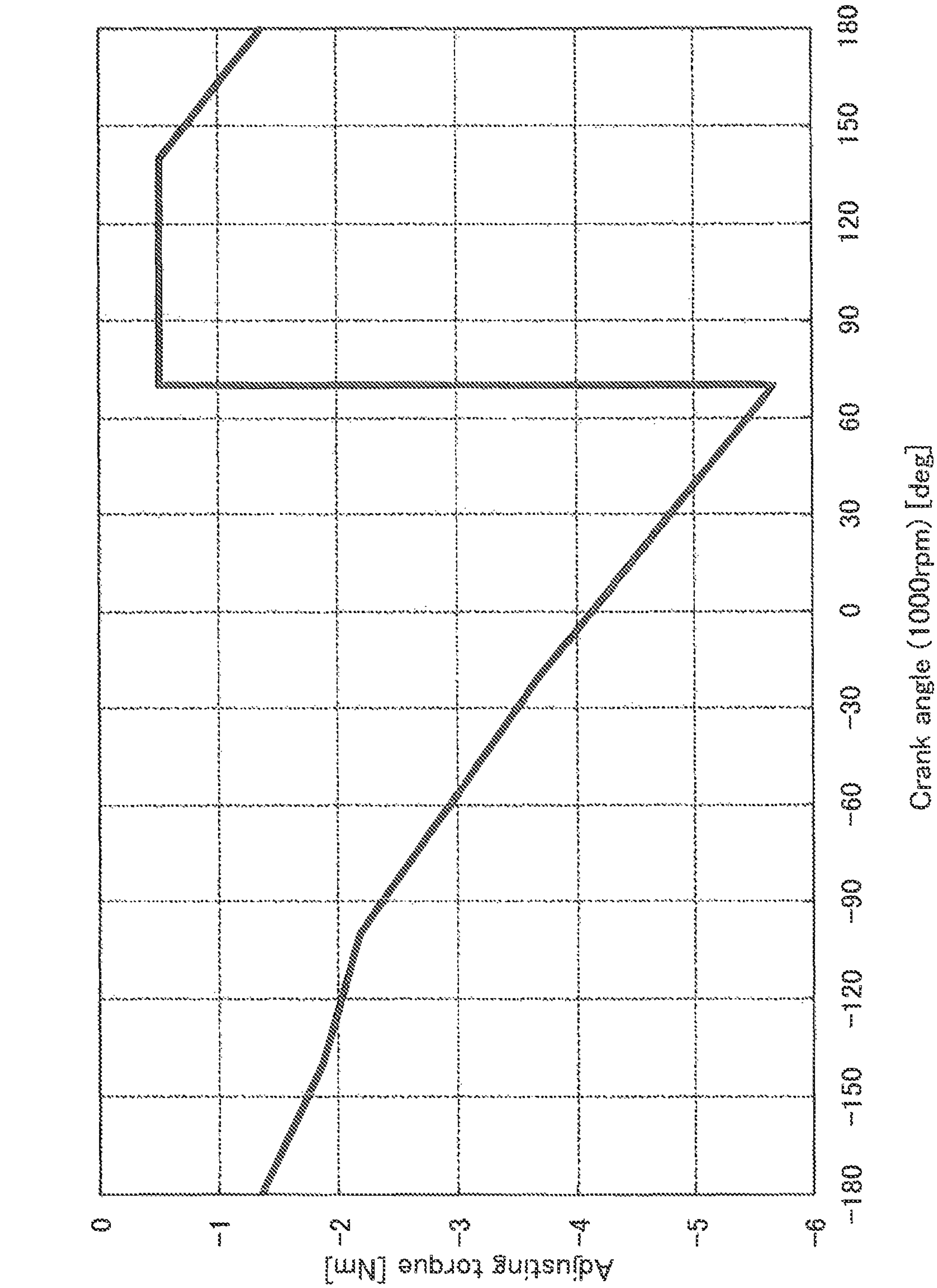

Adjusting torque [Nm]
0
−1
−2
−3
−4
−5
−6
Crank angle (1000rpm) [deg]
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180

FIG. 8

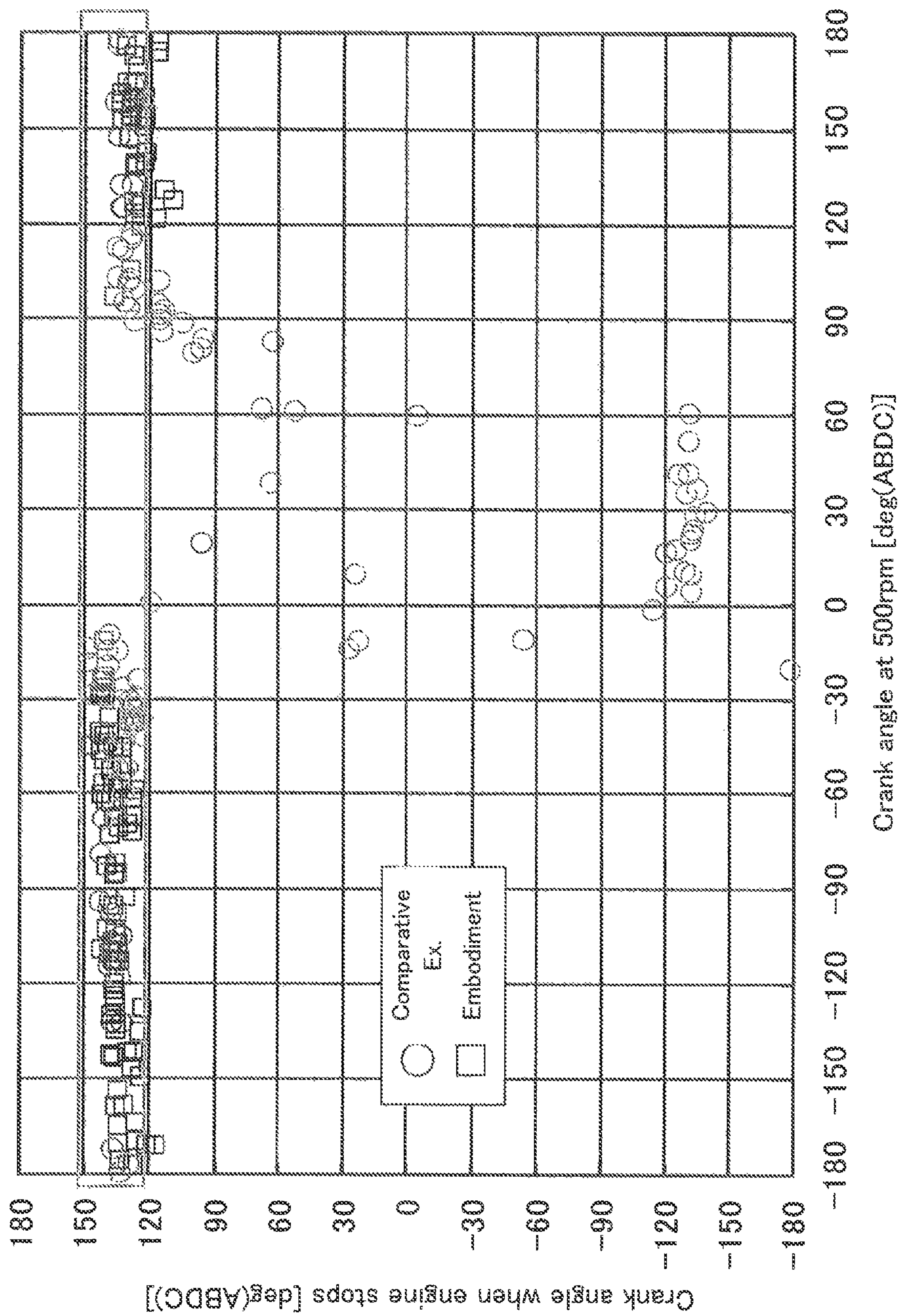

Crank angle at 500rpm [deg(ABDC)]
Crank angle when engine stops [deg(ABDC)]
Comparative Ex.
Embodiment
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150 180

FIG. 9

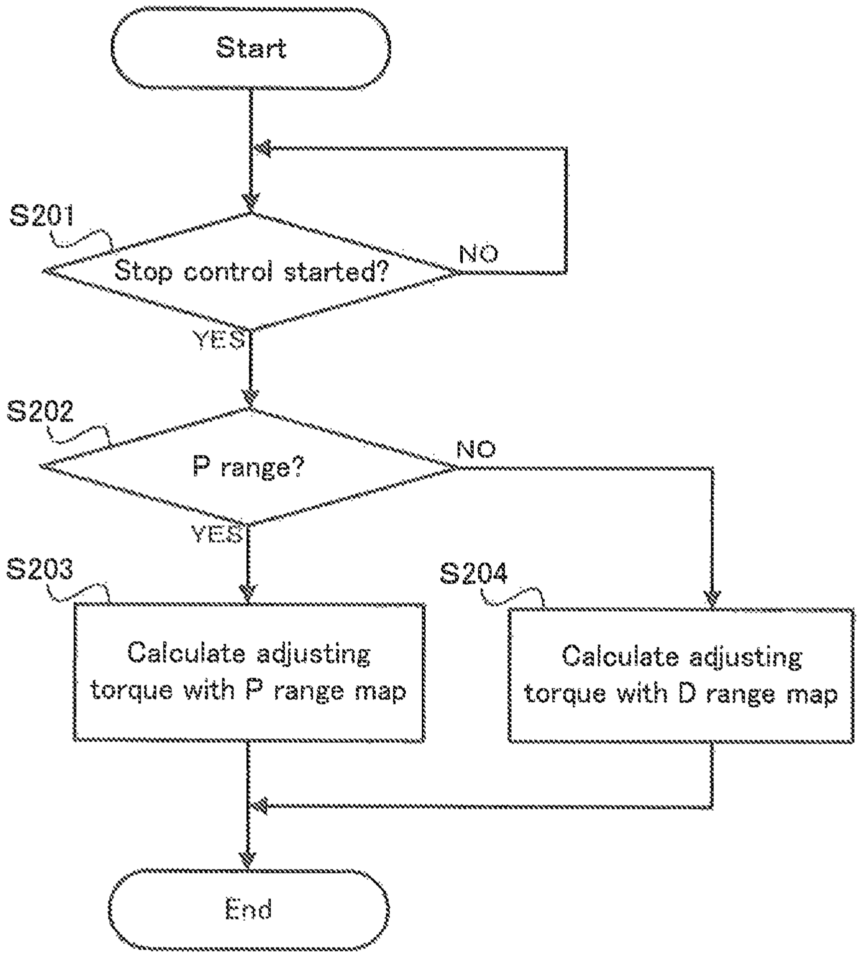

Start
S201
Stop control started?
NO
YES
S202
P range?
NO
YES
S203
Calculate adjusting torque with P range map
S204
Calculate adjusting torque with D range map
End

FIG. 10

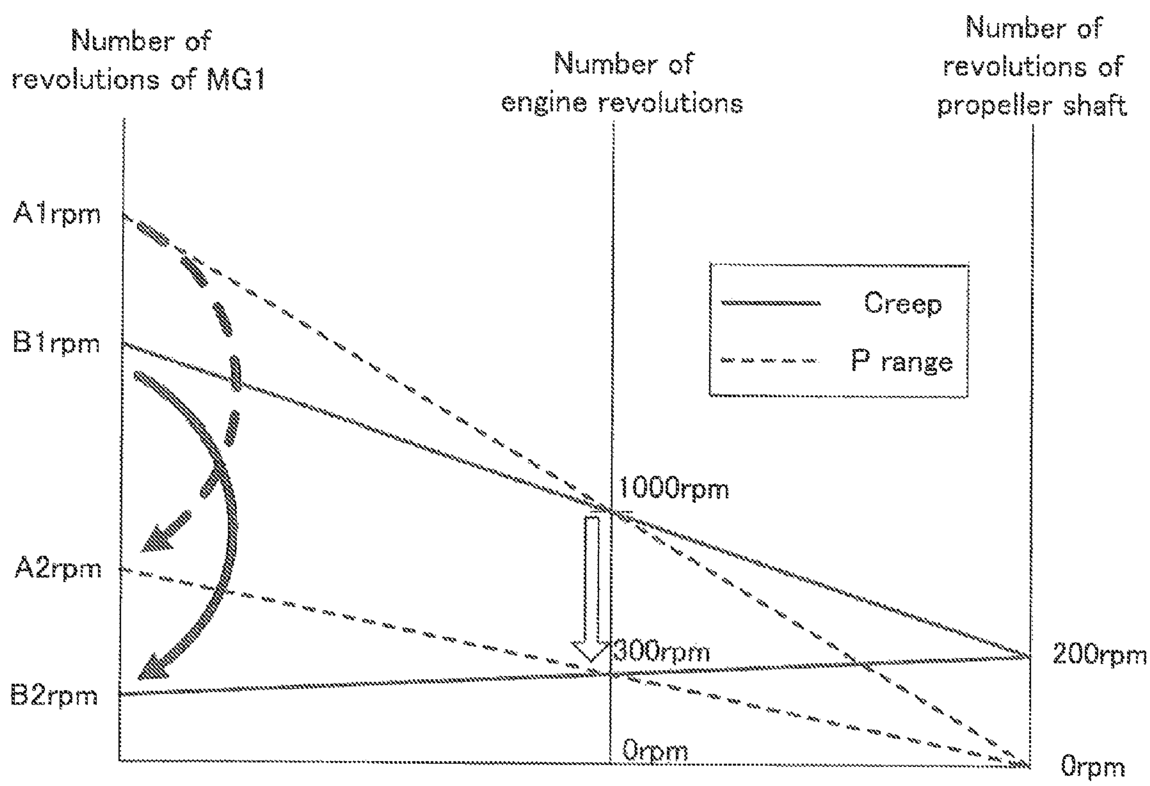

Number of
revolutions of MG1
Number of
engine revolutions
Number of
revolutions of
propeller shaft
A1rpm
B1rpm
A2rpm
B2rpm
Creep
P range
1000rpm
300rpm
200rpm
0rpm
0rpm

FIG. 11

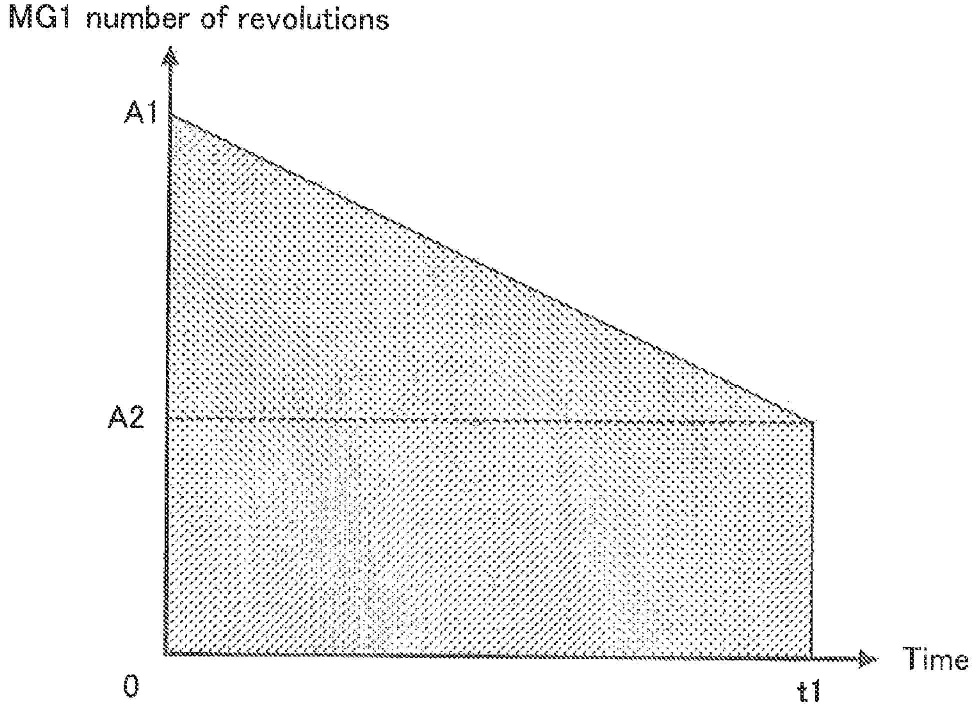
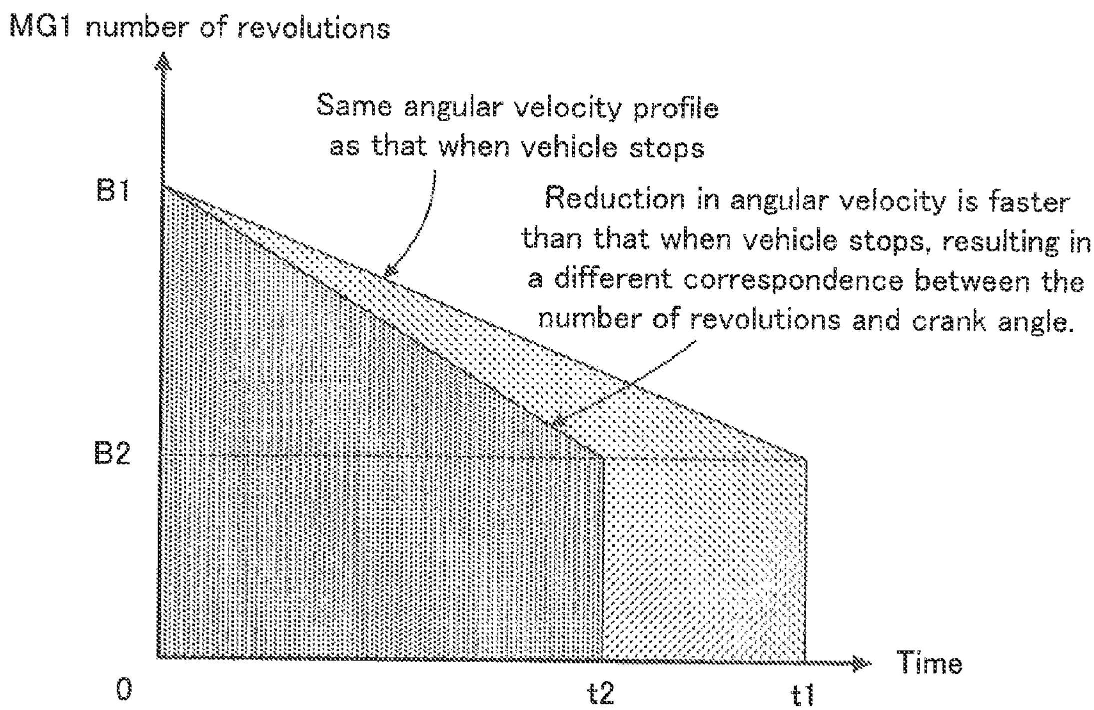

MG1 number of revolutions
A1
A2
0
t1
Time

FIG. 12


MG1 number of revolutions
Same angular velocity profile as that when vehicle stops
Reduction in angular velocity is faster than that when vehicle stops, resulting in a different correspondence between the number of revolutions and crank angle.
B1
B2
0
t2
t1
Time

STOP CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national phase application of International Application No. PCT/JP2011/078914, filed Dec. 14, 2011, the content of which is incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a stop control apparatus for an internal combustion engine configured to control a stop operation of the internal combustion engine installed in a vehicle such as, for example, an automobile.

BACKGROUND ART

This type of internal combustion engine is required to perform such control that a crank angle when the engine stops is within a predetermined range, for example, in order to suppress vibration when starting the engine. For the control of the crank angle, for example, a method of increasing a throttle opening degree immediately before the stop of the internal combustion engine is used. For example, it is proposed in Patent document 1 that the variation of the crank angle when the engine stops is reduced by increasing the throttle opening degree in an intake stroke immediately before the stop of the internal combustion engine and by increasing compression pressure in a compression stroke. For example, it is also proposed in Patent document 2 that the throttle opening degree in stop control is determined in accordance with the crank angle when the number of revolutions of the internal combustion engine is a predetermined value. It is also proposed in Patent document 3 that the throttle opening degree in stop control is determined in accordance with intake air density of the internal combustion engine.

PRIOR ART DOCUMENT

Patent Document

Patent document 1: Japanese Patent Application Laid Open No. 2004-232539

Patent document 2: Japanese Patent Application Laid Open No, 2010-116833

Patent document 3: Japanese Patent Application Laid Open No, 2007-327364

SUMMARY OF INVENTION

Subject to be Solved by the Invention

As described in the Patent documents 1 to 3 described above, in the method, of increasing the throttle opening degree, a piston in the intake stroke is braked due to intake negative pressure. Here, in the case of a four-or-more cylinder internal combustion engine, since any of the cylinders is always in the intake stroke, is a braking effect due to the intake negative pressure becomes constant and the crank angle is easily controlled. In the case of a three-or-less cylinder internal combustion engine, however, since there can be a time in which none of the cylinders is in the intake stroke, the braking effect due to the intake negative pressure does not become constant, and the crank angle is hardly controlled. In other

words, in the technologies described in the Patent documents 1 to 3 described above, there is such a technical problem that it is likely difficult to control the crank angle due to the generation of the intake negative pressure.

In view of the aforementioned problems, it is therefore an object of the present invention to provide a stop control apparatus for an internal combustion engine configured to preferably control the crank angle when the engine stops, even in the case of the three-or-less cylinder internal combustion engine.

Means for Solving the Subject

The above object of the present invention can be achieved by a stop control apparatus for an internal combustion engine is provided with: a motor configured to output torque to a crankshaft of the internal combustion engine; a number-of-revolutions detecting device configured to detect the number of revolutions of the internal combustion engine; a crank angle detecting device configured to detect a crank angle of the crankshaft of the internal combustion engine; a motor controlling device configured to control the motor to output adjusting torque which adjusts the crank angle when the internal combustion engine stops to have a desired value, when the internal combustion engine stops a throttle valve controlling device configured to control an opening degree of a throttle valve to be a predetermined opening degree in an intake stroke immediately before the internal combustion engine stops; and an adjusting torque determining device configured to determine the adjusting torque on the basis of the predetermined opening degree and the crank angle when the number of revolutions of the internal combustion engine has a predetermined value.

The stop control apparatus for the internal combustion engine of the present invention controls the operation of the three-or-less cylinder internal combustion engine when the internal combustion engine stops. The internal combustion engine of the present invention is configured, for example, as a power element which can supply power to a drive shaft of a vehicle, and can adopt various aspects regardless of, for example, a fuel type, a fuel supply aspect, a fuel combustion aspect, a configuration of an intake/exhaust system, cylinder arrangement and the like.

The stop control apparatus for the internal combustion engine of the present invention is provided with the motor configured to output the torque to the crankshaft of the internal combustion engine. The motor is configured as a motor generator such as, for example, a motor generator mounted on a hybrid vehicle. The stop control apparatus for the internal combustion engine of the present invention is also provided with the number-of-revolutions detecting device configured to detect the number of revolutions of the internal combustion engine, and the crank angle detecting device configured to detect the crank angle of the crankshaft of the internal combustion engine.

According to the stop control apparatus for the internal combustion engine of the present invention, the stop control of the internal combustion engine is started if the number of revolutions of the internal combustion engine detected on the number-of-revolutions detecting device is less than or equal to a predetermined threshold value. In the stop control of the internal combustion engine, for example, reducing torque for reducing the number of revolutions of the internal combustion engine is outputted from the motor. This gradually reduces the number of revolutions of the internal combustion engine, and eventually stops the internal combustion engine.

Here, particularly in the present invention, in the stop control of the internal combustion engine, the motor is controlled by the motor controlling device to output the adjusting torque for setting the crank angle when the internal combustion engine stops to have the desired value. If the motor outputs the aforementioned reducing torque, the sum of the reducing torque and the adjusting torque is outputted from the motor.

Moreover, in the present invention, in addition to the output of the adjusting torque described above, the opening degree of the throttle valve is controlled by the throttle valve controlling device to be a predetermined opening degree in the intake stroke immediately before the internal combustion engine stops. This reduces the intake negative pressure of an intake manifold in the intake stroke. In other words, the "predetermined opening degree" herein is obtained and set in advance, theoretically, experimentally, or experientially, as a value that can reduce the intake negative pressure.

The reduction in the intake negative pressure as described above reduces the braking effect of the piston due to the negative pressure in the intake stroke, and increases the other braking effect in the compression pressure. This makes it easy to stop the crank angle in a state of the compression stroke (preferably, immediately before top dead center in which vibration at the start of the internal combustion engine can be effectively suppressed).

Moreover in the present invention, the aforementioned adjusting torque is determined on the basis of the predetermined opening degree of the throttle valve and the crank angle when the number of revolutions of the internal combustion engine has the predetermined value. By determining the adjusting torque in this manner, the accuracy of the crank angle when the internal combustion engine stops can be further increased.

In the case of the four-or-more cylinder internal combustion engine, any of the cylinders is always in the intake stroke. Thus, even if the adjusting torque is not outputted, the braking effect due to the intake negative pressure becomes constant, and the crank angle is easily controlled. In the case of the three-or-less cylinder internal combustion engine as described in the present invention, however, there can be a period in which none of the cylinders is in the intake stroke. Thus, the braking effect due to the intake negative pressure does not become constant, and the crank angle is hardly controlled. Therefore, the present invention in which the opening degree of the throttle valve is controlled while the adjusting torque is outputted is extremely useful in practice.

As explained above, according to the stop control apparatus for the internal combustion engine of the present invention, it is possible to preferably control the crank angle when the engine stops, even in the case of the three-or-less cylinder internal combustion engine.

In one aspect of the stop control apparatus for the internal combustion engine of the present invention, wherein the predetermined opening degree is set as a value that allows intake negative pressure to be reduced to zero, in the intake stroke immediately before the internal combustion engine stops.

According to this aspect, if the opening degree of the throttle valve is set to the predetermined opening degree, the intake negative pressure of the intake manifold is reduced to zero. Incidentally, "zero" herein does not only mean that the intake negative pressure is completely zero, but also broadly includes that it is small enough to eliminate the adverse effect by the intake negative pressure described above.

The setting of the predetermined opening degree of the throttle valve as described above can certainly reduce the adverse effect of the intake negative pressure in the stop control of the internal combustion engine. Therefore, it is possible to control, the crank angle when the engine stops, more preferably.

In one aspect of the stop control apparatus for the internal combustion engine of the present invention, wherein the predetermined opening degree is fully open.

According to this aspect, the opening degree of the throttle valve in the intake stroke immediately before the internal combustion engine stops is controlled to be fully open. The study of the present inventor has revealed that the fully open throttle valve allows the engine to be certainly stopped with the crank angle having the desired value, regardless of, for example, specifications of the engine or the like. In this aspect, it is thus possible to control the crank angle when the engine stops, more preferably.

In one aspect of the stop control apparatus for the internal combustion engine of the present invention, wherein the stop control apparatus comprises a motor number-of-revolutions-detecting device configured to detect the number of revolutions of the motor, and the adjusting torque determining device increases the adjusting torque with increasing number of revolutions of the motor at a start of stop control of the internal combustion engine, and reduces the adjusting torque with reducing number of revolutions of the motor.

According to this aspect, the number of revolutions of the motor is detected by the motor number-of-revolutions detecting device. On the adjusting torque determining device, the adjusting torque is increased with increasing number of revolutions of the motor at the start of stop control of the internal combustion engine, and the adjusting torque is reduced with reducing number of revolutions of the motor.

As described above, if the adjusting torque is determined according to the number of revolutions of the motor, the deviation of the total amount of energy due to a difference in the number of revolutions is considered. It is thus possible to control the crank angle with higher accuracy when the engine stops.

In one aspect of the stop control apparatus for the internal combustion engine of the present invention, wherein the adjusting torque determining device reduces the adjusting torque if a gearshift of a transmission connected to the crankshaft of the internal combustion engine is in a D range for driving, in comparison with in a P range for stopping.

According to this aspect, the number of revolutions of the motor is indirectly determined depending on whether the gearshift of the transmission is in the D (drive) range for driving, or the P (parking) range for stopping. Specifically, in the case of the D range, the number of revolutions of the motor is determined to be smaller than that in the case of the P range.

In this manner, the number of revolutions of the motor can be easily estimated without actually detecting the number of revolutions of the motor. It is therefore possible to increase the accuracy of the crank angle control in a relatively simple configuration.

The operation and other advantages of the present invention will become more apparent from the embodiment explained below.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic configuration diagram conceptually illustrating a configuration of a hybrid vehicle.

FIG. **2** is a schematic configuration diagram conceptually illustrating a configuration of a hybrid drive apparatus.

FIG. **3** is a schematic configuration diagram conceptually illustrating a configuration of an engine.

FIG. **4** is a block diagram illustrating a configuration of an ECU,

FIG. **5** is a flowchart illustrating the operation of a stop control apparatus for an internal combustion engine in a first embodiment.

FIG. **6** is a chart illustrating changes in various parameters in operation of the stop control apparatus for the internal combustion engine in the first embodiment.

FIG. **7** is a map for calculating adjusting torque from a crank angle.

FIG. **8** is a graph illustrating a relation between a crank angle at 500 rpm and a crank angle when the engine stops.

FIG. **9** is a flowchart illustrating the operation of a stop control apparatus for an internal combustion engine in a second embodiment.

FIG. **10** is a nomogram illustrating the number of engine revolutions and the number of revolutions of MG**1**.

FIG. **11** is a graph illustrating time integration of an angular velocity when a vehicle stops.

FIG. **12** is a graph illustrating time integration of an angular velocity in low-speed driving.

MODES FOR CARRYING OUT THE INVENTION

Hereinafter, embodiments of the present invention will be explained with reference to the drawings.

Firstly, an entire configuration of a hybrid vehicle in which a stop control apparatus for an internal combustion engine in the embodiment is installed will be explained with reference to FIG. **1**. FIG. **1** is a schematic configuration diagram conceptually illustrating the configuration of the hybrid vehicle.

In FIG. **1**, a hybrid vehicle **1** in the embodiment is provided with a hybrid drive apparatus **10**, a power control unit (PCU) **11**, a battery **12**, an accelerator opening sensor **13**, a vehicle speed sensor **14**, and an ECU **100**.

The ECU **100** is provided with a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), and the like. The ECU **100** is an electronic control unit configured to control the operation of each unit of the hybrid vehicle **1**. The ECU **100** is configured to perform various controls of the hybrid vehicle **1** in accordance with a control program stored in, for example, the ROM or the like.

The PCU **11** converts direct-current (DC) power extracted from the battery **12** into alternating-current (AC) power and supplies it to motor generators MG**1** and MG**2** described later. The PCU **11** includes a not-illustrated inverter capable of converting AC power generated by the motor generators MG**1** and MG**2** into DC power and supplying it to the battery **12**. In other words, the PCU **11** is a power control unit configured to control input/output of electric power between the battery **12** and each motor generator, or input/output of electric power between the motor generators (i.e. in this case, the electric power is transferred between the motor generators without via the battery **12**). The PCU **11** is electrically connected to the ECU **100**, and the operation thereof is controlled by the ECU **100**.

The battery **12** is a chargeable storage battery which functions as an electric power supply source associated with the electric power for power running of the motor generators MG**1** and MG**2**. The amount of stored power of the battery **12** can be detected by the ECU **100** or the like.

The accelerator opening sensor **13** is a sensor configured to detect an accelerator opening degree Ta which is a manipulated variable or an operation amount of a not-illustrated accelerator pedal of the hybrid vehicle **1**. The accelerator opening sensor **13** is electrically connected to the ECU **100**, and the detected accelerator opening degree Ta is referred to by the ECU **100** with a regular or irregular period.

The vehicle speed sensor **14** is a sensor configured to detect a vehicle speed V of the hybrid vehicle **1**. The vehicle speed sensor **14** is electrically connected to the ECU **100**, and the detected vehicle speed V is referred to by the ECU **100** with a regular or irregular period.

The hybrid drive apparatus **10** is a power unit which functions as a power train of the hybrid vehicle **1**. Now, with reference to FIG. **2**, a detailed configuration of the hybrid drive apparatus **10** will be explained. FIG. **2** is a schematic configuration diagram conceptually illustrating the configuration of the hybrid drive apparatus.

In FIG. **2**, the hybrid drive apparatus **10** is provided mainly with an engine **200**, a power distribution mechanism **300**, the motor generator MG**1** (hereinafter abbreviated to "MG**1**" as occasion demands), the motor generator MG**2** (hereinafter abbreviated to "MG**2**" as occasion demands), an input shaft **400**, a drive shaft **500**, and a speed reduction mechanism **600**.

The engine **200** is a gasoline engine as one example of the "internal combustion engine" of the present invention. The engine **200** is configured to function as a main power source of the hybrid vehicle **10**. Now, with reference to FIG. **3**, a detailed configuration of the engine **200** will be explained. FIG. **3** is a schematic diagram illustrating a cross sectional configuration of the engine.

Incidentally, the "internal combustion engine" of the present invention conceptually includes an engine which has three or less cylinders and which is configured to extract a force generated when an air-fuel mixture containing various fuels such as, for example, gasoline, light oil or alcohol is burned in a combustion chamber within the cylinder(s), as a driving force through a physical or mechanical transmitting device such as, for example, a piston, a connecting rod, and a crankshaft, as occasion demands. As long as the concept is satisfied, the configuration of the internal combustion engine of the present invention is not limited to that of the engine **200** but may have various aspects.

Incidentally, even a four-or-more cylinder engine shall be included in the internal combustion engine of the present invention as long as it can be temporarily driven as the three-or-less cylinder engine due to cylinder deactivation or the like and is driven as the three-or-less cylinder engine during stop control described later.

Moreover, the engine **200** is an engine in which a plurality of cylinders **201** are aligned in a direction perpendicular to the paper; however, only one cylinder **201** will be explained in FIG. **3** because the individual cylinders **201** have the same configuration.

In FIG. **3**, the engine **200** is configured to enable the air-fuel mixture to be burned via an ignition operation of an ignition apparatus **202** in which a spark plug (whose reference numeral is omitted) is partially exposed in a combustion chamber in the cylinder **201**. The engine **200** is also configured to convert a reciprocating motion of a piston **203** caused by an explosive force due to the combustion, into a rotational motion of a crankshaft **205** through a connecting rod **204**.

In the vicinity of the crankshaft **205**, there is disposed a crank position sensor **206** configured to detect a rotational position of the crankshaft **205** (i.e. a crank angle). The crank position sensor **206** is electrically connected to the ECU **100** (not illustrated), and the ECU **100** is configured to calculate the number of engine revolutions NE of the engine **200** on the basis of a crank angle signal outputted from the crank position sensor **206**.

In the engine **200**, the air sucked from the exterior (or intake air) is supplied through an intake tube **207** and an intake port **210** to the inside of the cylinder **201** upon opening of an intake valve **211**. On the other hand, a fuel injection valve of an injector **212** is exposed in the intake port **210**, and the fuel injection valve is configured to inject fuel to the intake port **210**. The fuel injected from the injector **212** is mixed with the intake air before or after the opening timing of the intake valve **211**, thereby making the aforementioned air-fuel mixture.

The fuel is stored in a not-illustrated fuel tank and is supplied to the injector **212** through a not-illustrated delivery pipe by the operation of a not-illustrated feed pump. The air-fuel mixture burned in the cylinder **201** becomes an exhaust gas and is supplied to an exhaust tube **215** through an exhaust port **214** upon opening of an exhaust valve **213** which opens or closes in conjunction with the opening or closing of the intake valve **211**.

On the other hand, on the upstream side of the intake port **210** in the intake tube **207**, there is disposed a throttle valve **208** configured to adjust an intake air amount associated with the intake air supplied through a not-illustrated cleaner. The throttle valve **208** is one example of the "throttle valve" of the present invention and is configured such that a driving state thereof is controlled by a throttle valve motor **209** which is electrically connected to the ECU **100**. Incidentally, the ECU **100** controls the throttle valve motor **209** basically to obtain a throttle opening degree according to the opening degree of an accelerator pedal which is not illustrated (i.e. the aforementioned accelerator opening degree Ta); however, the ECU **100** can also adjust the throttle opening degree without a driver's intention through the operation control of the throttle valve motor **209**. In other words, the throttle valve **208** is configured as a kind of electronically-controlled throttle valve.

In the exhaust tube **215**, a three-way catalyst **216** is disposed. The three-way catalyst **216** is a catalyst apparatus configured to reduce NOx (nitrogen oxide) in the exhaust gas emitted from the engine **200** and to oxidize CO (carbon monoxide) and HC (hydrocarbon) in the exhaust gas. Incidentally, a form which can be adopted by the catalyst apparatus is not limited to the three-way catalyst as described above. Instead of or in addition to the three-way catalyst, various catalysts such as, for example, a. NSR catalyst (or NOx storage-reduction catalyst) or an oxidation catalyst may be disposed.

Moreover, in the exhaust tube **215**, there is disposed an air-fuel ratio sensor **217** configured to detect an exhaust air-fuel ratio of the engine **200**. Moreover, in a water jacket disposed in a cylinder block which accommodates the cylinder **201**, there is disposed a water temperature sensor **218** for detecting a coolant temperature associated with a coolant (LLC) circulated and supplied to cool the engine **200**. Each of the air-fuel ratio sensor **217** and the temperature sensor **218** is electrically connected to the ECU **100**, and each of the detected air-fuel ratio and the detected coolant temperature is recognized by the ECU **100** with a regular or irregular detection period.

Back in FIG. **2**, the motor generator MG**1** is one example of the "motor" of the present invention, and is an electric motor generator having a power running function for converting electrical energy into kinetic energy and a regeneration function for converting kinetic energy into electrical energy. The motor generator MG**2**, as in the motor generator MG**1**, is an electric motor generator having the power running function for converting electrical energy into kinetic energy and the regeneration function for converting kinetic energy into electrical energy. Incidentally, the motor generators MG**1** and MG**2** may be configured, for example, as synchronous motor generators. For example, each of the motor generators MG**1** and MG**2** is provided with a rotor having a plurality of permanent magnets on an outer circumferential surface and a stator in which a three-phase coil for forming a rotating magnetic field is wound; however, each of the motor generators may have another configuration.

The power distribution mechanism **300** is provided with a sun gear S**1** provided in a central portion thereof, a ring gear R**1** provided concentrically on an outer circumference of the sun gear S**1**, a plurality of pinion gears P**1** which are disposed between the sun gear S**1** and the ring gear R**1** and each of which revolves around the outer circumference of the sun gear S**1** while rotating on its own axis, and a carrier C**1** which supports a rotating shaft of each pinion gear.

Here, the sun gear S**1** is coupled with a rotor RT**1** of the MG**1** through a sun gear shaft **310** and the number of revolutions thereof is equivalent to the number of revolutions Nmg**1** of the MG**1** (hereinafter referred to as "MG**1** number-of-revolutions Nmg**1**" as occasion demands). The ring gear R**1** is coupled with a rotor RT**2** of the MG**2** through a clutch **710**, the drive shaft **500**, and the speed reduction mechanism **600**, and the number of revolutions thereof has an unambiguous relation with the number of revolutions Nmg**2** of the MG**2** (hereinafter referred to as "MG**2** number-of-revolutions Nmg**2**" as occasion demands). Moreover, the carrier C**1** is coupled with the input shaft **400** coupled with the aforementioned crankshaft **205** of the engine **200**, and the number of revolutions thereof is equivalent to the number of engine revolutions NE of the engine **200**. In the hybrid drive apparatus **10**, each of the MG**1** number-of-revolutions Nmg**1** and the MG**2** number-of-revolutions Nmg**2** is detected with a regular period, by a rotation sensor such as a resolver, and is transmitted to the ECU **100** with a regular or irregular period.

On the other hand, the drive shaft **500** is coupled with drive shafts SFR and SFL which drive a right front wheel FR and a left front wheel FL as driving wheels of the hybrid vehicle **1**, respectively, via the speed reduction mechanism **600** which is a speed reducing apparatus including various reduction gears and differential gears. Therefore, motor torque Tmg**2** supplied from the motor generator MG**2** to the drive shaft **500** is transmitted to each drive shaft via the speed reduction mechanism **600**, and a driving force from each driving wheel transmitted through each drive shaft is inputted to the motor generator MG**2** via the speed reduction mechanism **600** and the drive shaft **500** in the same manner. Therefore, the MG**2** number-of-revolutions Nmg**2** has an unambiguous relation with the vehicle speed V of the hybrid vehicle **1**.

The power distribution mechanism **300** is configured to distribute engine torque Te which is supplied from the engine **200** to the input shaft **400** through the crankshaft **205**, to the sun gear S**1** and the ring gear R**1** at a predetermined ratio (a ratio according to a gear ratio between the gears) by the carrier C**1** and the pinion gears P**1**, and is configured to divide the power of the engine **200** into two systems, under the above configuration.

Next, a specific configuration of the ECU **100** which constitutes a part of the stop control apparatus for the internal combustion engine in the embodiment will be explained with reference to FIG. **4**. FIG. **4** is a block diagram illustrating the configuration of the ECU **100**.

In FIG. **4**, the ECU **100** in the embodiment is provided with a number-of-engine-revolutions detection unit **110**, a crank angle detection unit **120**, an engine stop control determination unit **130**, a MG torque calculation unit **140**, a MG torque control unit **150**, and a throttle control unit **160**.

The number-of-engine-revolutions detection unit **110** is one example of the "number-of-revolutions detecting device" of the present invention, and detects the number of revolutions NE of the engine **200** on the basis of information about the crank angle which is obtained from, for example, the crank position sensor **206** (refer to FIG. **3**). The number of revolutions NE of the engine **200** detected on the number-of-engine-revolutions detection unit **110** is outputted to the engine stop control determination unit **130**.

The crank angle detection unit **120** is one example of the "crank angle detecting device" of the present invention, and detects the crank angle of the crankshaft **205** on the basis of the information about the crank angle which is obtained from, for example, the crank position sensor **206**. The crank angle detected on the crank angle detection unit **120** is outputted to the MG torque calculation unit **140**.

The engine stop control determination unit **130** performs various determinations in the stop control of the engine **200** on the basis of the number of revolutions NE of the engine **200** detected on the number-of-engine-revolutions detection unit **110**. The engine stop control determination unit **130** has, for example, at least one threshold value for the number of revolutions NE of the engine **200** in order to perform the engine stop control, and determines whether or not to perform various controls in the engine stop control depending on whether or not the detected number of revolutions NE exceeds the threshold value. The engine stop control determination unit **130** controls each of the MG torque calculation unit **140** and the throttle control unit **160** if determining to perform the engine stop control.

The MG torque calculation unit **140** is one example of the "adjusting torque determining device" of the present invention, and determines torque to be outputted from the MG**1**. The MG torque calculation unit **140** calculates reducing torque for reducing the number of revolutions of the engine **200** in the engine stop control, and adjusting torque for adjusting the position of the crank angle. Here, in particular, the aforementioned adjusting torque is calculated by using the crank angle which is obtained from the crank angle detection unit **120**. The MG torque calculation unit **140** stores therein, for example, a map for deriving the adjusting torque from the crank angle. A value calculated on the MG torque calculation unit **140** is outputted to the MG torque control unit **150**.

The MG torque control unit **150** is one example of the "motor controlling device" of the present invention. The MG torque control unit **150** controls the motor generator MG**1** to output the torque which is calculated on the MG torque calculation unit **140**.

The throttle control unit **160** is one example of the "throttle valve controlling device" of the present invention. The throttle control unit **160** drives the throttle valve motor **209** (refer to FIG. **3**), thereby controlling the opening degree of the throttle valve **208**. The throttle control unit **160** in the embodiment particularly sets the throttle valve **208** to have a predetermined opening degree which is set in advance, upon engine stop control. The operation upon engine stop control will be detailed later.

The ECU **100** which includes the aforementioned parts is an electronic control unit which is integrally configured, and all the operations related to the aforementioned parts are configured to be performed by the ECU **100**. The physical, mechanical, and electrical configurations of the aforementioned parts in the present invention are not limited to this example. Far example, each of the parts may be configured as various computer systems, such as a plurality of ECUs, various processing units, various controllers, or micro computer apparatuses.

Next, the operation of the stop control apparatus for the internal combustion engine in the embodiment will be explained, with two embodiments exemplified.

<First Embodiment>

Firstly, the operation of the stop control apparatus for the internal combustion engine in the first embodiment will be explained with reference to FIG. **5** to FIG. **8**. FIG. **5** is a flowchart illustrating the operation of the stop control apparatus for the internal combustion engine in the first embodiment. FIG. **6** is a chart illustrating changes in various parameters in operation of the stop control apparatus for the internal combustion engine in the first embodiment.

In FIG. **5** and FIG. **6**, in operation of the stop control apparatus for the internal combustion engine in the first embodiment, firstly, the number of revolutions NE of the engine **200** is detected on the number-of-engine-revolutions detection unit **110** (step S**101**). If the number of revolutions NE of the engine **200** is detected, it is determined on the engine stop control determination unit **130** whether or not the detected value is 1200 rpm or less (step S**102**). Incidentally, the value of 1200 rpm herein is a threshold value for determining whether or not to start the engine stop control, and is stored in advance in the engine stop control determination unit **130**.

If it is determined that the detected value is 1200 rpm or less (the step S**102**: YES), the reducing torque to be outputted from the MG**1** is calculated on the MG torque calculation unit **140**, and the MG**1** is controlled to output the calculated reducing torque by the MG torque control unit **150** (step S**103**).

If the reducing torque cannot be sufficiently outputted from the MG**1**, for example, due to Win limit or the like in the battery **12**, it is possible to compensate for the output shortage of the MG**1** by temporally reducing the opening degree of the throttle valve **208** before the output of the reducing torque and producing the braking effect due to the intake negative pressure.

Then, the number of revolutions NE of the engine **200** is detected again on the number-of-engine-revolutions detection unit **110** (step S**104**). If the number of revolutions NE of the engine **200** is detected, it is determined on the engine stop control determination unit. **130** whether or not the detected value is 1000 rpm or less (step S**105**). Incidentally, the value of 1000 rpm herein is a threshold value for determining whether or not to start the output of the adjusting torque for adjusting the crank angle, and is stored in advance in the engine stop control determination unit **130**.

If it is determined that the detected value is 1000 rpm or less (the step S**105**: YES), firstly, the value of the crank angle at that time point, is detected on the crank angle detection unit **120** (step S**106**). Then, the adjusting torque to be outputted from the MG**1** is calculated by the MG torque calculation unit **140** on the basis of the detected value of the crank angle (step S**107**).

Now, a specific method of calculating the adjusting torque will be explained with reference to FIG. **7**. FIG. **7** is a map for calculating the adjusting torque from the crank angle. Incidentally, the map in FIG. **7** illustrates a torque value for controlling the crank angle after the engine stop to be about 120 deg to 150 deg, which is immediately before the top dead center.

By using the map as illustrated in FIG. **7**, the value of the adjusting torque to be outputted can be unambiguously determined from the value of the crank angle when the number of revolutions NE of the engine **200** is 1000 rpm. The map as described above can be prepared, for example, by repeating a test for studying what type of torque is to be outputted to set the crank angle after the engine stop at a desired position.

Back in FIG. **5** and FIG. **6**, if the adjusting torque is calculated, the MG**1** is controlled to output the calculated adjusting torque, by the MG torque control unit **150** (step S**108**). The adjusting torque is outputted, as illustrated in a hatched portion in FIG. **6**, in a form of being added to the reducing torque which has been outputted by that time.

Then, the number of revolutions NE of the engine **200** is detected again on the number-of-engine-revolutions detection unit **110** (step S**109**). If the number of revolutions NE of the engine **200** is detected, it is determined on the engine stop control determination unit **130** whether or not the detected value is 500 rpm or less (step S**110**). Incidentally, the value of 500 rpm herein is a threshold value for determining whether or not to set the opening degree of the throttle valve **208** fully open, and is stored in advance in the engine stop control determination unit **130**.

It is also possible to suppress driving noise caused by damper resonance, by bringing the threshold value herein close to a resonance band of a damper (e.g. 350 rpm). Specifically, if the resonance band of the damper is overlapped in the compression stroke, the driving noise caused by the damper resonance deteriorates due to compression reaction force. In contrast, if a threshold value which allows the opening degree of the throttle valve **208** to be set fully open is set to be the resonance band of the damper, it is possible to effectively suppress the driving noise, because the resonance band of the damper can be passed through in the intake stroke immediately before the engine stop.

If it is determined that the detected value is 500 rpm or less (the step S**110**: YES), the throttle valve motor **209** is driven by the throttle control unit **160**, and the opening degree of the throttle valve **208** is set fully open. By setting the opening degree of the throttle valve **208** fully open, the intake negative pressure of an intake manifold is reduced and brought close to the atmospheric pressure. This reduces the braking effect of the piston **203** caused by the negative pressure in the intake stroke, and increases the other braking effect in the compression pressure. This makes it easy to stop the crank angle immediately before the top dead center.

Here, the explanation was given to the case where the opening degree of the throttle valve **208** shall be set fully open; however, the opening degree is not necessarily set fully open as long as it has a value that can eliminate an adverse effect of the intake negative pressure in the intake stroke described above.

Lastly, the effect of the engine stop control by the stop control apparatus for the internal combustion engine in the first embodiment will be explained with reference to FIG. **8**, FIG. **8** is a graph illustrating a relation between the crank angle at 500 rpm and the crank angle when the engine stops. A comparative example in FIG. **8** illustrates a result in a case where only the control of setting the throttle valve **208** fully open is performed out of the engine stop control in the first embodiment, and the adjusting torque is not outputted.

As illustrated in FIG. **8**, in the comparative example in which the adjusting torque is not outputted, if the crank angle at 500 rpm which is the number of engine revolutions NE of the engine **200** is near a range of −30 deg to 90 deg, the crank angle when the engine **200** stops deviates from a target value (i.e. 120 deg to 150 deg). On the other hand, in the embodiment in which the adjusting torque is outputted, regardless of the crank angle when the number of engine revolutions NE of the engine **200** is 500 rpm, the crank angle when the engine **200** stops is in the range of the target value in almost all the cases. According to the engine stop control in the embodiment as described above, it is possible to control the crank angle with extremely high accuracy.

If the engine **200** is a multi-cylinder engine having four or more cylinders, since any of the cylinders is always in the intake stroke, the braking effect due to the intake negative pressure becomes constant and the crank angle is easily controlled even if the adjusting torque is not outputted. In the three-or-less-cylinder engine **200** as in the embodiment, however, since there can be a time in which none of the cylinders is in the intake stroke, the braking effect due to the intake negative pressure does not become constant, and the crank angle is hardly controlled. Therefore, the engine stop control in the embodiment in which the opening degree of the throttle valve **208** is adjusted while the adjusting torque is outputted is extremely useful.

As explained above, according to the stop control apparatus for the internal combustion engine in the first embodiment, it is possible to preferably control the crank angle when the engine stops.

<Second Embodiment>

Next, the operation of a stop control apparatus for an internal combustion engine in a second embodiment will be explained with reference to FIG. **9** to FIG. **12**. FIG. **9** is a flowchart illustrating the operation of the stop control apparatus for the internal combustion engine in the second embodiment. The second embodiment is partially different from the aforementioned first embodiment in operation, but is substantially the same as the first embodiment regarding the other basic operation. Thus, in FIG. **9**, a part of the processing illustrated in FIG. **5** is omitted as occasion demands, and only the processing different from that in the first embodiment is illustrated.

In FIG. **9**, in operation of the stop control apparatus for the internal combustion engine in the second embodiment, if the engine stop control is started (step S**201**: YES), it is determined whether or not a gearshift of the hybrid vehicle **1** is in a P range (step S**202**). In other words, it is determined whether the gearshift of the hybrid vehicle **1** is in the P range for stopping the vehicle, or a D range for driving.

If it is determined that the gearshift of the hybrid vehicle **1** is in the P range (the step S**202**: YES), the adjusting torque is calculated by using a P range map (step S**203**). If it is determined that the gearshift of the hybrid vehicle **1** is not in the P range (i.e. is in the D range) (the step S**202**: NO), the adjusting torque is calculated by using a D range map (step S**204**).

Here, particularly in the case of the D range, the number of the revolutions of the MG**1** is presumably smaller than that in the case of the P range. Thus, if the D range map is used, the adjusting torque is calculated as a smaller value than that in the case where the P range map is used. This is because rotational energy is proportional to the squares of the number of revolutions.

Hereinafter, the difference in the adjusting torque in the P range and the D range described above will be specifically explained with reference to FIG. **10** to FIG. **12**, FIG. **10** is a nomogram illustrating the number of engine revolutions and the number of revolutions of the MG**1**. FIG. **11** is a graph illustrating time integration of an angular velocity when the vehicle steps. FIG. **12** is a graph illustrating time integration of an angular velocity in low-speed driving.

As illustrated in FIG. **10**, a study is conducted on a case where the number of engine revolutions is reduced from 1000 rpm to 300 rpm in a vehicle during stop in the P range and in a vehicle in a creep state (i.e. in low-speed driving in the D range).

In the vehicle during stop in the P range, when the number of engine revolutions is reduced from 1000 rpm to 300 rpm, the number of revolutions of the MG**1** is reduced from A1 rpm to A2 rpm. On the other hand, in the vehicle in the creep state, when the number of engine revolutions is reduced from 1000 rpm to 300 rpm, the number of revolutions of the MG**1** is reduced from B1 rpm to B2 rpm. As is clear from the drawing, A1>B1>A2>B2 with regard to each value of the number of revolutions.

In FIG. **11**, when the number of engine revolutions of the vehicle during stop in the P range is reduced from 1000 rpm to 300 rpm, if it takes a time t**1** to uniformly output the reducing torque of 15 Nm, energy outputted from the MG**1** can be calculated by multiplying a time integration value of the angular velocity (i.e. an area of a trapezoidal portion in the drawing) by the torque (i.e. 15 Nm) of the MG**1**,

In FIG. **12**, when the number of engine revolutions of the vehicle in the creep state is reduced from 1000 rpm to 300 rpm, in the same manner, if it takes a time t**2** to uniformly output the reducing torque of 15 Nm, energy outputted from the MG**1** can be calculated by multiplying a time integration value of the angular velocity (i.e. an area of a smaller trapezoidal portion in the drawing) by the torque (i.e. 15 NM) of the MG**1**.

As is clear from FIG. **12**, however, since the time t**2** is shorter than the time t**1**, a reduction in the angular velocity in the creep state is faster than that when the vehicle stops, resulting in a different correspondence between the number of revolutions and the crank angle. In order to solve the difference in angular velocity profile as described above, the torque of the MG**1** may be set smaller than 15 Nm, and it may be set to take the time t**1** to reduce the number of revolutions. In other words, in the D range with the smaller number of revolutions of the MG**1**, the same control as in the P range can be applied by setting the torque of the MG**1** smaller than that in the P range.

As explained above, according to the stop control apparatus for the internal combustion engine in the second embodiment, it is possible to preferably control the crank angle even in the different ranges of the vehicle (i.e. in the different numbers of revolutions of the MG**1** causing a difference in total amount of energy).

The present invention is not limited to the aforementioned embodiment, but various changes may be made, if desired, without departing from the essence or spirit of the invention which can be read from the claims and the entire specification. A control stop apparatus for an internal combustion engine, which involve such changes, is also intended to be within the technical scope of the present invention,

DESCRIPTION OF REFERENCE CODES

1 hybrid vehicle
10 hybrid drive apparatus
11 PCU
12 battery
13 accelerator opening sensor
14 vehicle speed sensor
100 ECU
110 number-of-engine-revolutions detection unit
120 crank angle detection unit
130 engine stop control determination unit
140 MG torque calculation unit
150 MG torque control unit
160 throttle control unit
200 engine
201 cylinder
203 piston
205 crankshaft
206 crank position sensor
208 throttle valve
209 throttle valve motor
210 intake port
212 injector
214 exhaust port
300 power distribution mechanism
500 drive shaft
600 speed reduction mechanism
MG**1**, MG**2** motor generator

The invention claimed is:

1. A stop control apparatus for an internal combustion engine configured to control operation of a three-or-less cylinder internal combustion engine when the internal combustion engine stops, said stop control apparatus comprising:

a motor configured to output torque to a crankshaft of the internal combustion engine;

a number-of-revolutions detecting processor programmed to detect the number of revolutions of the internal combustion engine;

a crank angle detecting processor programmed to detect a crank angle of the crankshaft of the internal combustion engine;

a motor controlling processor programmed to control the motor to output adjusting torque which adjusts the crank angle when the internal combustion engine stops to have a desired value, when the internal combustion engine stops;

a throttle valve controlling processor programmed to control an opening degree of a throttle valve to be a predetermined opening degree in an intake stroke immediately before the internal combustion engine stops;

an adjusting torque determining processor programmed to determine the adjusting torque on the basis of the crank angle when the number of revolutions of the internal combustion engine has a predetermined value;

a power division mechanism having a first rotating element, a second rotating element, and a third rotating element which can mutually perform differential rotation, the first rotating element being connected to the internal combustion engine, the second rotating element being connected to the motor, and the third rotating element being connected to a drive shaft; and

a motor number of revolutions detecting processor programmed to detect the number of revolutions of the motor,

wherein:

the adjusting torque determining processor is further programmed to increase the adjusting torque with increasing number of revolutions of the motor at a start of stop control of the internal combustion engine, and reduces the adjusting torque with the reducing number of revolutions of the motor, and

the motor controlling processor is further programmed to output the adjusting torque for a predetermined time.

2. The stop control apparatus for the internal combustion engine according to claim **1**, wherein the predetermined opening degree is set as a value that allows intake negative pressure to be reduced to zero, in the intake stroke immediately before the internal combustion engine stops.

3. The stop control apparatus for the internal combustion engine according to claim **1**, wherein the predetermined opening degree is fully open.

4. The stop control apparatus for the internal combustion engine according to claim **1**, wherein

the adjusting torque determining processor is further programmed to reduce the adjusting torque if a gearshift of a transmission connected to the crankshaft of the internal combustion engine is in a D range for driving, in comparison with in a P range for stopping.

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